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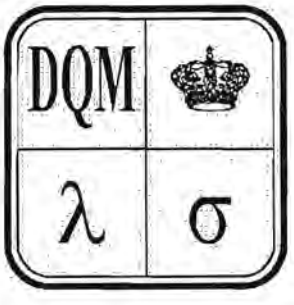

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An example of extreme increase of pump station's energy efficiency

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Summary
An example of extreme increasing of pump stations (PS) energy efficiency, achieved by PS "Berilovac" system reengineering is presented in the paper. Analysis of PS operation is performed, and corresponding Technical solution for energy efficiency is suggested. Based on electrical energy consumption in the PS in the last four years it is shown that the consumption is reduced for 40- 50% by the applied technical solution, compared to the situation before. The period of investment return was less then two years. These results, no doubt, set the suggested approach to energy efficiency increase far above to all other approaches for energy efficiency increasing used in practice, and it could be applied in all other pump systems. Beside these extreme savings, the work on further energy efficiency increase in the pump stations continues through the several new projects, so more positive results could be expected in the years to come.
Key words: *Extreme energy efficiency increasing, pump stations, municipal systems.*

1. INTRODUCTION

Problems related to energy efficiency increase are becoming more important these days, as prices of electric energy are getting higher. When production costs in water supplying systems are analyzed, it can be concluded that electric energy costs are dominant, which becomes obvious considering the need for turning on several pumps at the same time, in order to maintain constant water supply for all consumers. Every-day experience has shown that a total cost of electric energy, consumed by a certain pump drive, exceeds tens of times costs of its purchase, installation and maintenance. Therefore, it is necessary to pay a great attention to right selection of pumps, as well as to methods for reducing of power consumption.

When usual methods for pump station (PS) energy efficiency are analyzed, it becomes clear that all of them always start from currently existing situation, and they always suggest different ways of automatization of PS operation, such as applying of frequency regulators, subsinchronous thyristor cascades, reactive power compensation, different systems for monitoring and control of PS operations, etc., However, according to author's experience, overall effects of such approach are incomparably inferior to effects achieved from seriously performed reengineering of a system. The theme of this paper is just one example, carried out through three projects [3], [9], [10], of Ministry of science and environmental protection, which has achieved extreme increase of PS energy efficiency.

2. DESCRIPTION OF "BERILOVAC" PUMP STATION

PS "Berilovac" is situated in outskirts of Pirot, on the road to Krupac village. Since it was built in 1976, it has been operating as a main pump station in water supply system of the town of Pirot. The PS type is "booster", and it is placed on a pipeline which brings water from "Krupac" and "Gradište" capping. Hydro installation of PS "Berilovac" is projected for operation of four pumps. By the end of first half of 2000, pump system was composed of three pumps of SPS 88 type and one pump of SPS 7/B type, manufactured by "Jastrebac", Niš. Operating mode of PS involved one SPS 88 pump working alone or in parallel with SPS 7/B pump, depending on water consumption. Combinations of pumps which provided greater water flow were used only in cases of highly increased consumption, when two SPS 88 pumps were plugged in.

After receiving new pumps from a donation, two old SPS 88 pumps were replaced by CPH 20-2/350 and CPH 20-2/336 "Grundfos" pumps, while another new CPH 20-2/350 was kept in reserve. When new pumps started their operation, new great problems occurred, like driving motors overloads, rapid damaging of bearings, heavy noise during operation, etc. Therefore, these pumps, in a short period of time while they have been working, had to operate with throttled valves, in order to reduce motor overloading, but problems with bearings and loud noise remained. Described problems endangered regular water supply, especially during warmest summer months, when PS "Berilovac" worked without reserve. In that sense, drop-out of any pump would have meant inevitable restrictions in water supplying.

Having in mind a necessity of finding a correct technical solution which would provide stability and reliability of water supplying, an analysis of PS operating problems was carefully performed [1]. Because of a drastic increase of electric energy costs, it was extremely logical to pay attention to possible technical measures for PS energy efficiency improvements [2].

Aggravating circumstances for analysis came out from the fact that flow and pressure measuring devices were not installed in PS. In order to overcome this problem, during the realization of a project [3], an indirect method for determination of a H(Q) characteristics of PS pipeline [4], based on measured electrical values of driving induction motors [5], has been invented. Although a similar method, regarding to a much complex system (water supplying system- turbine-turbine regulator- synchronous motor), was previously experimentally confirmed in the case of reversible hydro powerplant "Bajina Bašta" [6], one of the earliest public presentation of a proposed approach [7] was exposed to a sharp criticism in some scientific and expert circles. In such situations, the best way to prove validity of certain scientific approach is to present results obtained from practical test. Therefore, the main goal of this paper is to inform all interested parts about results gained in PS "Berilovac". Some of them have already been published [8], but savings reached in that moment were considerably smaller, which contributes to a greater importance of this paper.

3. A PROPOSAL OF A TECHNICAL SOLUTION FOR ENERGY EFFICIENCY INCREASE

For a purpose of analysis of problems mentioned above, H(Q) characteristics of PS pipeline was approximately estimated, using the indirect method explained in [4]. Already known pipeline characteristic has been used for determination of installed pumps operating areas, and for analysis of problems in their operation [1]. Causes of described problems were found in inadequate selection of pumps, because all of pumps were designed to operate with heads much greater then ones occurring in normal operating regimes of PS "Berilovac". It was shown that in all operating regimes of observed pumps, operating point left pump's expected operating range. Therefore, pumps were operating with flow values greater then nominal. Such flows led to reduced efficiency and increased loss of energy [3], [7].

After recognizing causes of problems mentioned above, a detailed analysis has been performed, in order to establish appropriate technical solutions for their solving and increasing PS energy efficiency [2]. Following possibilities were discussed: 1) reducing of impeller diameters; 2) replacing pumps with keeping existing induction motors drives; 3) replacing pumps and their drives with new ones; 4) installing of frequency regulators; 5) installing of subsynchronous thyristor cascades.

Analysis showed that possibilities 1) and 4) would not provide wanted improvement. Even though installing of subsynchronous thyristor cascade had numerous advantages over installing of frequency regulators, it would not offer quality solution to problems in PS operating. Therefore, all of technical and economic reasons pointed at replacing of pumps, or whole assemblies pump-driving induction motor, as the only acceptable solution for described situation. It was concluded that 110 kW pumps should be replaced by corresponding 75 kW pumps. Having in mind a possibility of exploiting of existing 75 kW pump assembles (CPH 15-2/336) in CS "Kavak", the management of JP "Vodovod i kanalizacija", Pirot, has decided to purchase new pump assemblies. As an optimal choice, 75 kW pumps NK 150-400/380, with MMG 280 S-4 motors, were selected. According to suggestion of a research team, in March 2003, a described pump-motor assembly has been purchased and installed. It is shown in Figure 1, in order to make a comparison to an 110 kW pump-motor assembly previously used.

One year later, another identical 75 kW assembly was acquired. In April 2004, one more 110 kW assembly was replaced and the current situation was established (Figure 2).

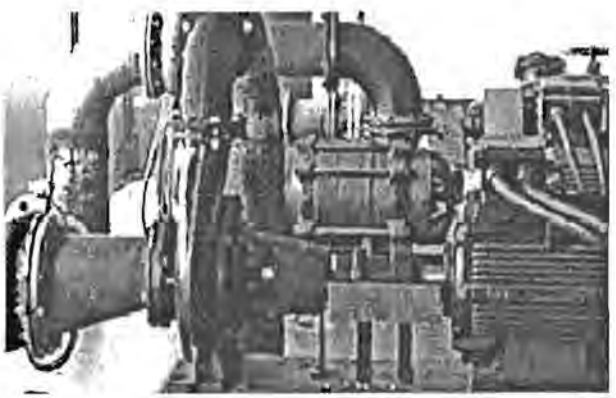

Figure 1. The pump NK 150/400/380 in PS "Berilovac" after installation

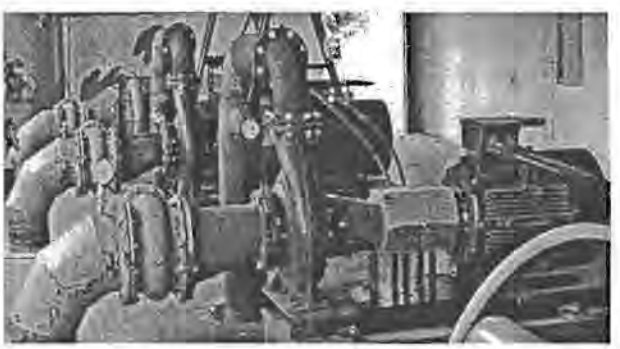

Figure 2. PS "Berilovac" after installation of another NK 150/400/380 pump (present state)

4. A TECHNICAL AND ECONOMICAL ANALYSIS OF APPLIED SOLUTION

After application of proposed technical solution, putting in operation the first NK pump assembly, and tests performed during 2003, it become clear that selected pump assembly completely resolved all problems which never occurred again.

Cavitation disappeared, as well as possibility for considerable motor overload, because total load was only a few percent greater then nominal even in situation when pump's valve was completely opened. Furthermore, it was shown that percentage errors in estimation of electrical values in different PS operating regimes, previously performed only according to proposed indirect approach, did not exceed 2%, which was surely within a range of tolerable deviation. Putting this pump in operation, PS "Berilovac" energy efficiency increased, which lead to scientifically reduced energy consumption and corresponding costs.

First conclusions about energy efficiency after installing of the first NK pump could be drawn from pumps power data. Namely, reducing pumps power from 110 kW to 75 kW, says enough about reduced energy consumption.

However, the easiest way to explain accomplished savings is to analyze total electric energy consumption for the period May-August, in years 2001-2004. This period was selected because all of pump stations are working with their maximal capacity during summer months, which is the best guarantee that energy efficiency of PS "Berilovac" was neither achieved on the account of reduced amount of water delivered to the consumers, nor because increased amount of water pumped by other pump stations.

Results presented in Table 1 show that replacing only one of the pumps in PS "Berilovac" lead to reducing total maximal engaged power for more then one third (34.78%), comparing to previous situation, which signifficaly reduced peak electric load.

Table 1. An analysis of summary electric energy consumption after replacement of the first pump in PS "Berilovac"

	Summary electric energy consumption for the period May- August			Decrease in electric energy consumption in 2003. comparing to average consumption in 2001. and 2002. [%]
Tariff	2001	2002	2003	
AH [KWh]	334800	323200	228800	(1-228800/329000)*100 = 30.46%
AL [KWh]	148800	133200	118800	(1-118800/141000)*100 = 15.70%
RH [KVAr]	225200	220400	154400	(1-154400/222800)*100 = 30.70%
RL [KVAr]	108400	95600	84800	(1-84800/102000)*100 = 16.86%
MAX [KW]	1068	956	660	(1-660/1012)*100 = 34.78%

Active and reactive power consumption during the high tariff was reduced by more then 30%. On the other hand, active and reactive power consumption during the low tariff was reduced by 16%, which shows that pumps are working more intensively during the period of low tariff.

It is important to say that tests performed after installing of the other NK pump did not record any problems in its operation and that it showed great operating stability. The whole system showed great improvement in its operation, when two NK pumps worked in parallel, by reducing the noise and vibrations in the greatest extent, comparing to any other operating pump combinations. Analysis of electricity bills for the period May-August 2004. showed additional significant reduction of electric energy consumption, after putting in operation the second NK pump,

comparing to values showed in Table 1. This reduction was as high as 40- 45%, comparing to average consumption in the period May-August 2002 (Table 2).

Table 2. An analysis of summary electric energy consumption after replacement of the second pump in PS "Berilovac"

	Summary electric energy consumption for the period May- August			Decrease in electric energy consumption in 2004. comparing to average consumption in 2001. and 2002. [%]
Tariff	2001	2002	2004	
AH [KWh]	334800	323200	181600	(1-181600/329000)*100 = 44.80%
AL [KWh]	148800	133200	84400	(1-84400/141000)*100 = 40.14%
RH [KVAr]	225200	220400	124400	(1-124400/222800)*100 = 44.16%
RL [KVAr]	108400	95600	60000	(1-60000/102000)*100 = 41.18%
MAX [KW]	1068	956	564	(1-564/1012)*100 = 44.27%

Series of analysis, performed after installing of total flow measuring device in PS "Berilovac", proved that selection of new pumps was optimal, because gained efficiency in all operating regimes became very close to the maximal efficiency for this type of pumps.

5. CONCLUSION

An example of extreme increase of pump station's energy efficiency is presented in the paper. It is demonstrated that selection of optimal technical solution enables reducing of electric energy consumption by 40- 45%, comparing to previous situation, as well as increasing of stability, reliability and operating life-time of a system, combined with great reduction in maintenance costs. Besides extremely large financial savings, significant scientific contribution lays in the fact that full technical and economic analysis, as well as selection of optimal solution, was performed without any information about flows and pressures in pipeline of the PS, relaying only to the indirect method developed by authors, which was exposed to a criticism in some circles, as it was mentioned above. Authors believe that presented results are the best proof of validity of proposed approach.

It is interesting to point out that two practically new pumps with relatively few operating hours were completely eliminated from PS operation, because all of relevant technical and economic parameters emphasized great advantages of proposed approach, comparing to any other known. These advantages become even more obvious in cases of replacing of old pumps that have been working for a long period of time. Experience has shown that in case of PS "Berilovac" period of return of invested assets was shorter then two years.

Applied solutions do not clash with any other conventional methods for energy efficiency increase (reactive power compensation, subsynchronous thyristor cascades, etc.). Therefore, it can be predicted with great certainty that additional reduction of power consumption for more then 50%, will occur in PS "Berilovac" in following years.

At the end, it is important to say that described approach is fully applicable in all other pump stations (water supplying systems, industrial plants, sewerage systems, irrigation systems, etc.)

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